Boeing Technology
Phantom Works

Superconducting Flywheel Development

Phil Johnson, FESS Program Manager – Boeing Phantom Works

DOE Energy Storage Systems – 2006 Peer Review

Funded in part by the Energy Storage Systems Program of the U.S. Department Of Energy (DOE/ESS) through Sandia National Laboratories (SNL

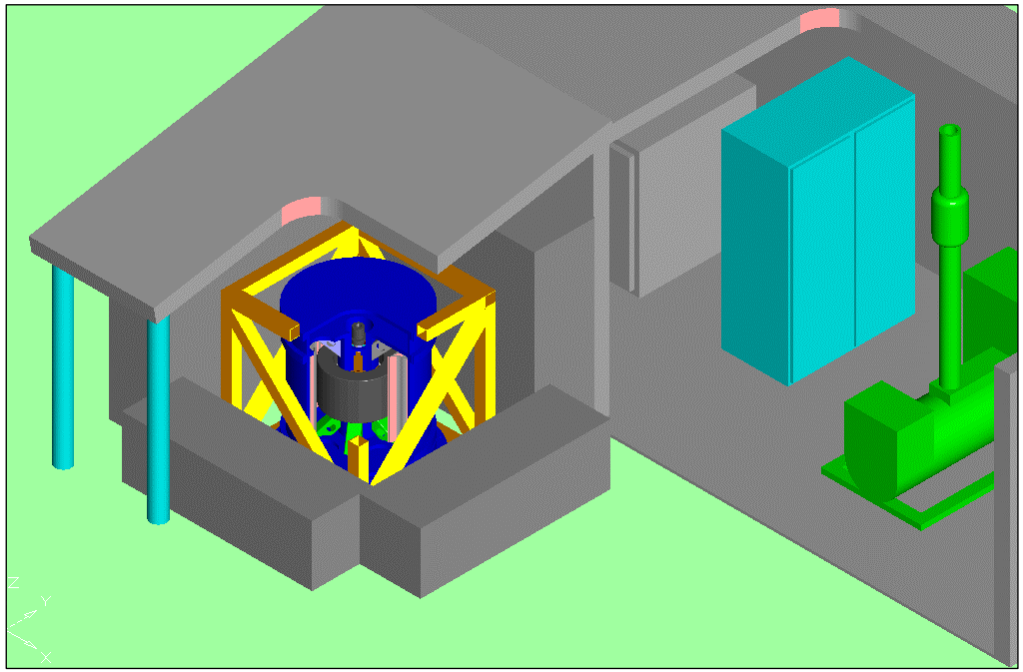
50kW / 5kWh Flywheel Energy Storage System
Off-Grid Demo System

Objective:

•Design, build and deliver a flywheel energy storage system tailored for off-grid applications utilizing a High Temperature Superconducting (HTS) Bearing

Goal:

•Successfully integrate the FESS system into a demonstration site



One of three deployment options for the demo system, shown in relation to diesel genset and balance of system.

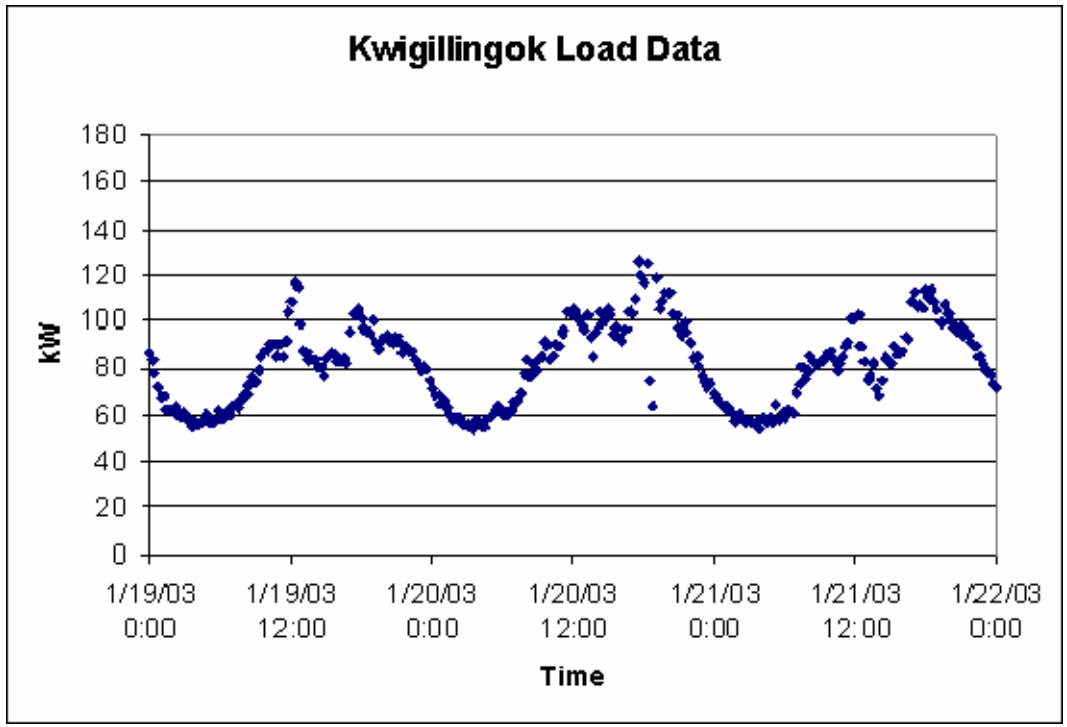
Status:

•The qualification testing of the 5kWh rotor is complete
•The direct cooled HTS bearing fabrication is complete
•The initial testing of the HTS bearing exceeded expectations
•Funding interruption has slid schedule

Typical Load Profile for Remote Village in Alaska

Kwigillingok, Alaska (population 338)

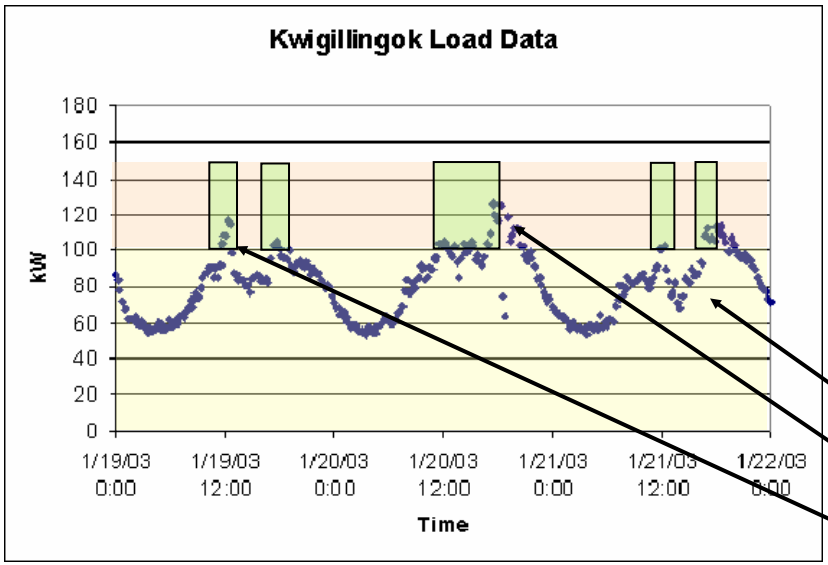
Photo and data credits Virtual Tourist.com & encyclopedia.thefreedictionary.com

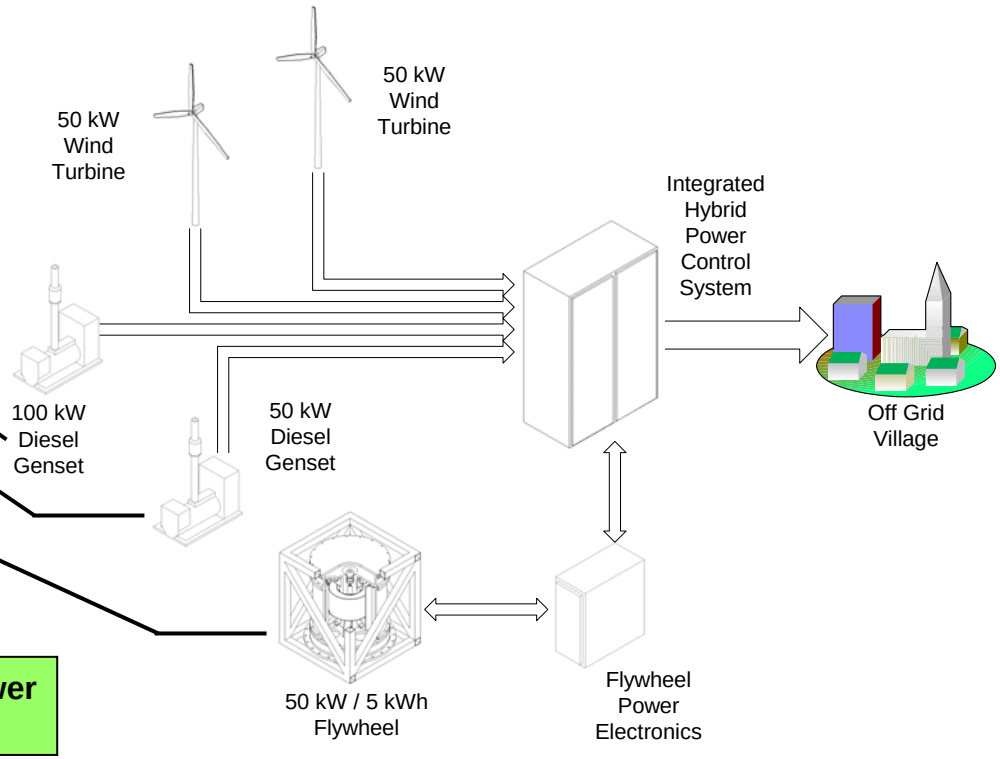


- Now served by multiple diesel systems
- Reasonable match for 50 kW power system

- *Data provided courtesy of Alaska Energy Authority*

Proposed System Architecture for Deployment of a 50kW / 5kWh Flywheel Energy Storage System





Flywheel Energy Storage System would supply power during short peak demand periods

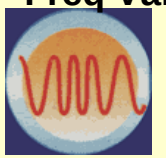
<u>Benefits of Using FESS Instead of Idling 2nd Generator on Standby</u>

- **Reduce Generator Maintenance by 50% (estimate)**
- **Reduce Fuel Costs by $80k/yr (estimate)**
- **Lower Pollution**

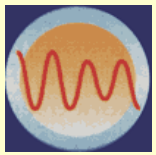
Flywheel Energy Storage Systems Basic Operation

Surges

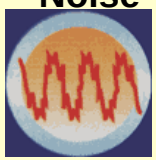
Freq Var



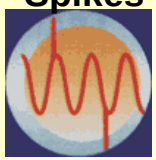
Sags



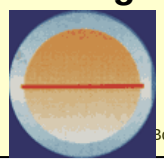
Noise

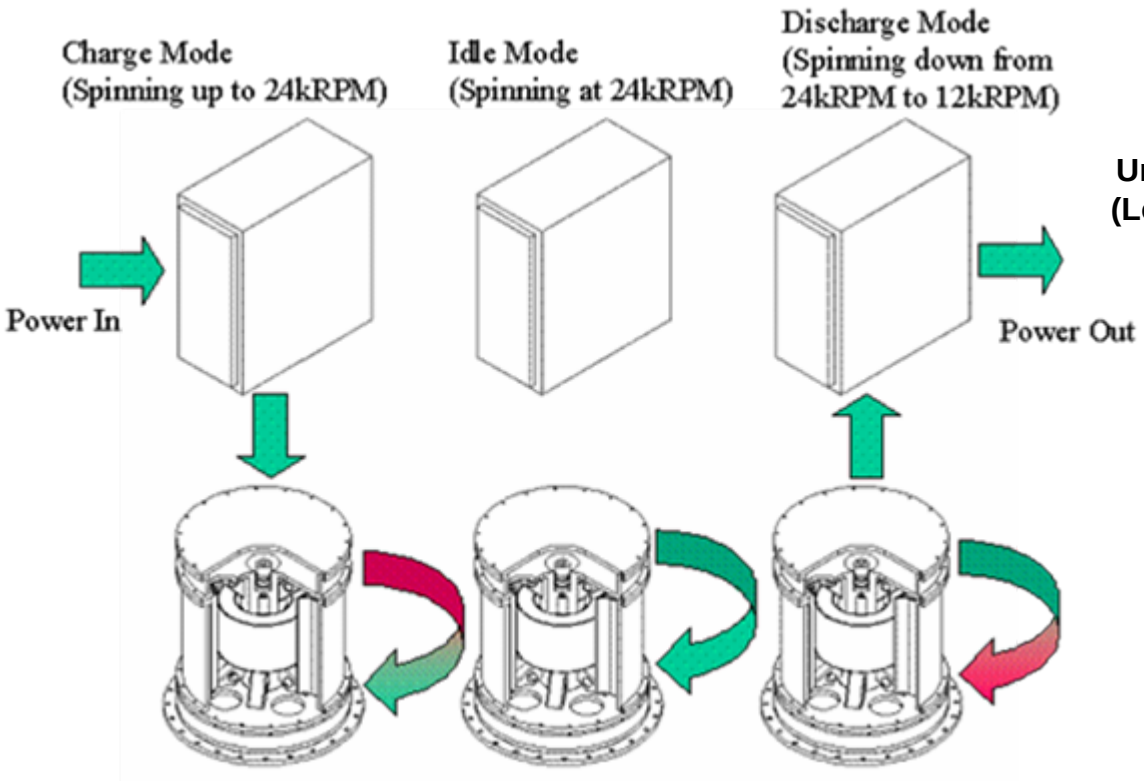


Spikes

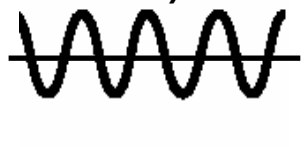


Outage

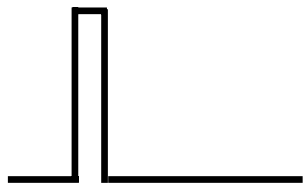




Uninterrupted Regulated (Load Leveled) Power Out



High Pulsed Power Out



50kW / 5kWh Flywheel Energy Storage System Project Roadmap

6/99 – 9/99

Phase I: Application ID and Initial System Specification

- Applications
- Characteristics
- Planning

5/00 – 3/01

3/01 – 11/-01 (funding interruption)

1/04 – 05/-04 (funding interruption)

Phase I: Significant Outputs

- **Unit characteristics**
- **System specification document**

11/01 – 12/05

Phase II: Component Development and Testing

- Rotor/bearing
- Materials
- Reliability

Phase II: Significant Outputs

- **Prelim design complete**
- **HTS crystal array complete**
- **Material lifetime data**
- **Rotor improvements complete**
- **Rotor qualification testing complete**
- **HTS Direct Cooled HTS bearing**

10/06 – 10/07

6/06 – 10/-06 (funding interruption)

Phase III: System Integration and Laboratory Testing

- Site selection
- Detail design
- Build/buy
- System test

Phase III:

- **Started October 17, 2006**

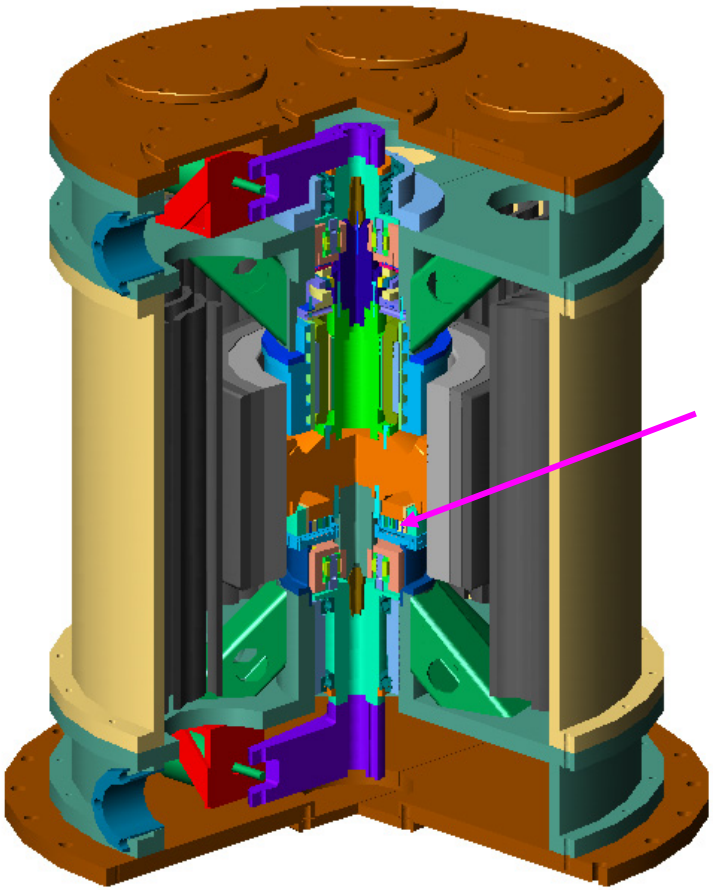
10/07 – 9/08

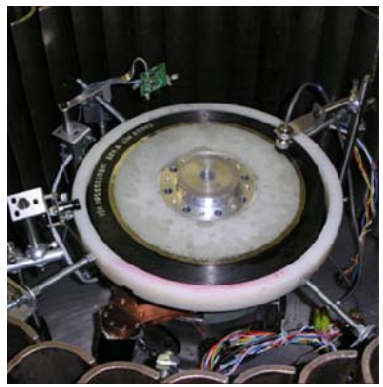
Phase IV: Field Test

- Install
- Conduct field testing
- Post-test evaluation

50 kW / 5kWh Flywheel Energy Storage System 2006 Component Focus

- **Fabrication of direct cooled HTS Bearing**
- **Initial testing of direct cooled HTS Bearing exceeded expectations**



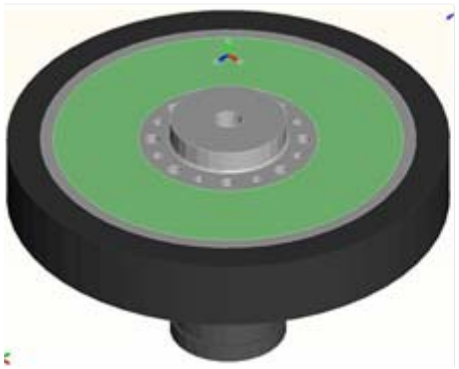


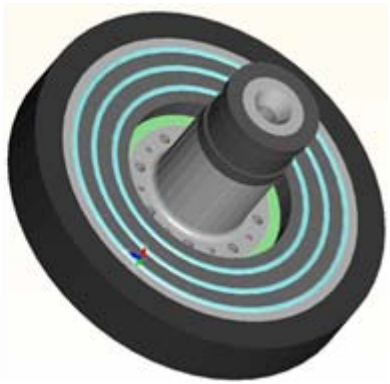
HTS Bearing Stator

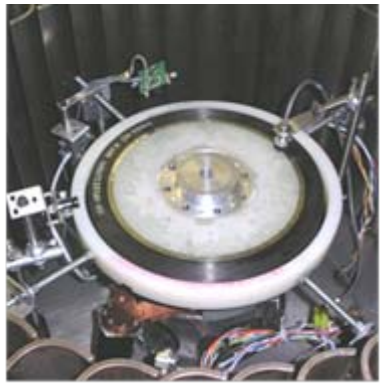
HTS Bearing Rotor

Hex YBCO

Challenge with HTS Stability Magnetic Assembly Resolved







During assembly by subcontractor, magnet segments chipped and magnets did not align properly.

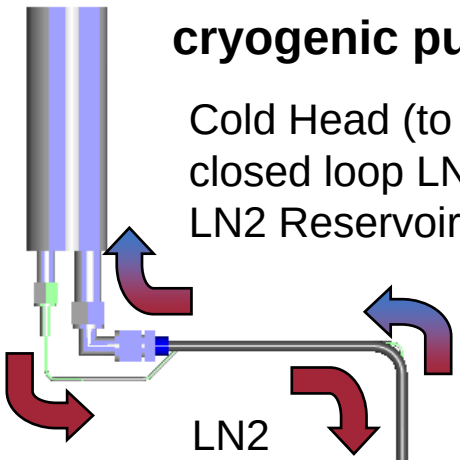
Worked with subcontractor to resolve manufacturing and assembly issues resulting in a superior assembly

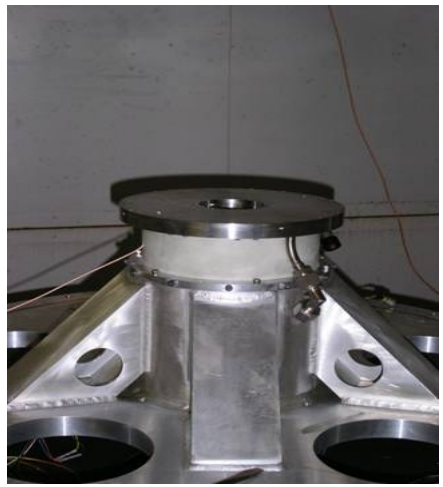
Improved Stability Magnet Subassembly

Previous DOE/Boeing Flywheel terrestrial cryogenics

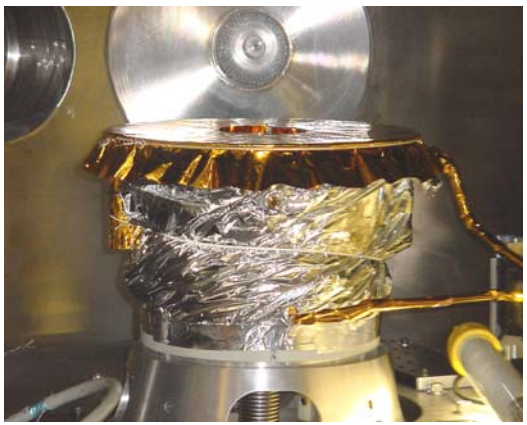
Use of a Thermosiphon eliminated a cryogenic pump requirement

Cold Head (to re-condense N2 gas for closed loop LN2 Operation) & ~ Liter Size LN2 Reservoir





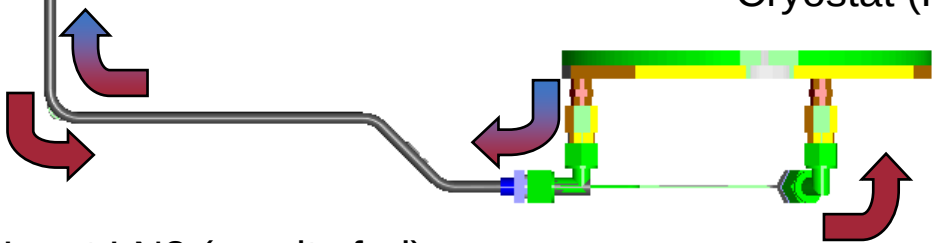
HTS Stability Bearing Cryostat Installed in DOE 5 kWh Flywheel



HTS Stability Bearing Cryostat Installed in DOE 10 kWh Flywheel

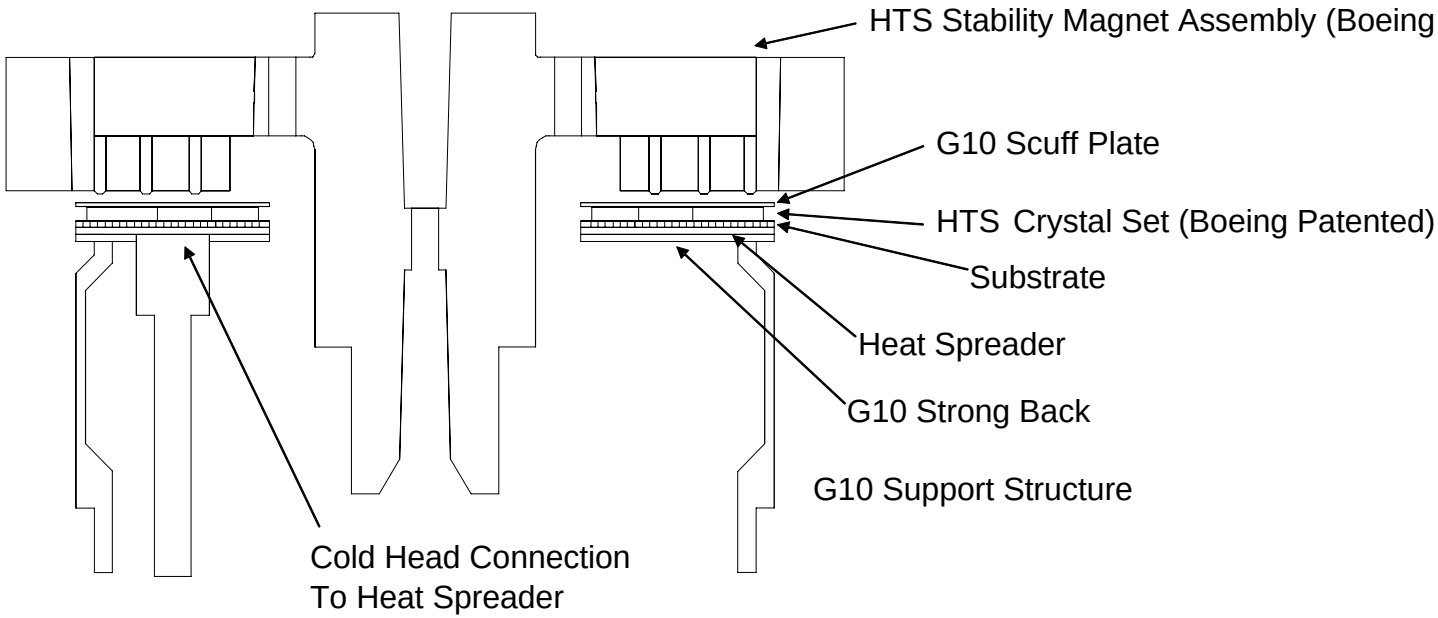
Return LN2 & N2 (Two phase flow)

Cryostat (HTS)



Input LN2 (gravity fed)

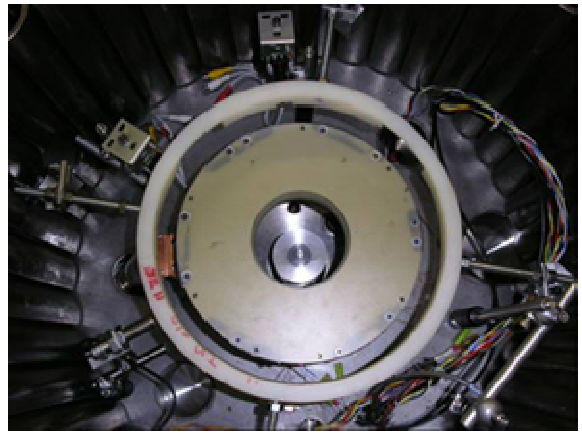
Direct Cooling Approach on HTS Bearing

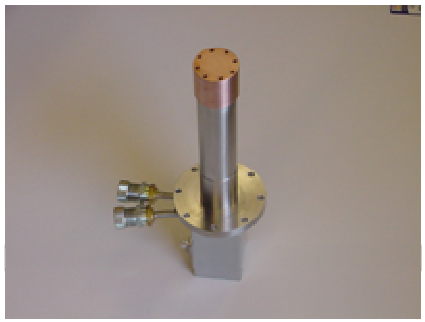


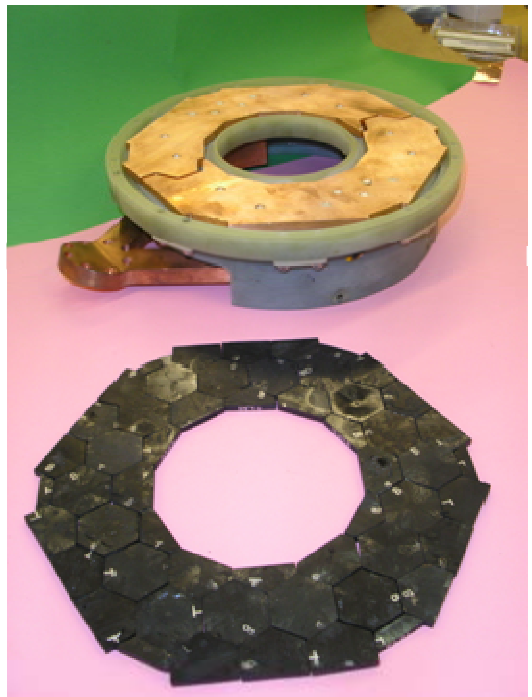
Benefits:

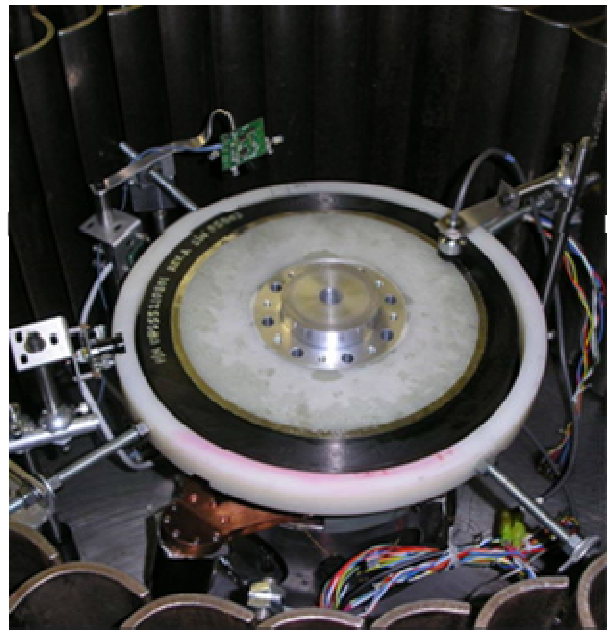
- **~60% fewer parts**
- **Reduced power requirements**
- **Eliminates the requirement for LN2**
- **Reduces maintenance**
  - **Constraint is now the compressor service requirement of maintenance check once every 10,000 hours for Gifford McMahon technology, once every 20,000 hours for Pulse Tube technology**

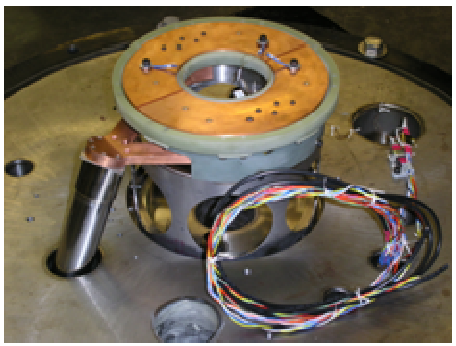
Direct Cooling Approach on HTS Bearing



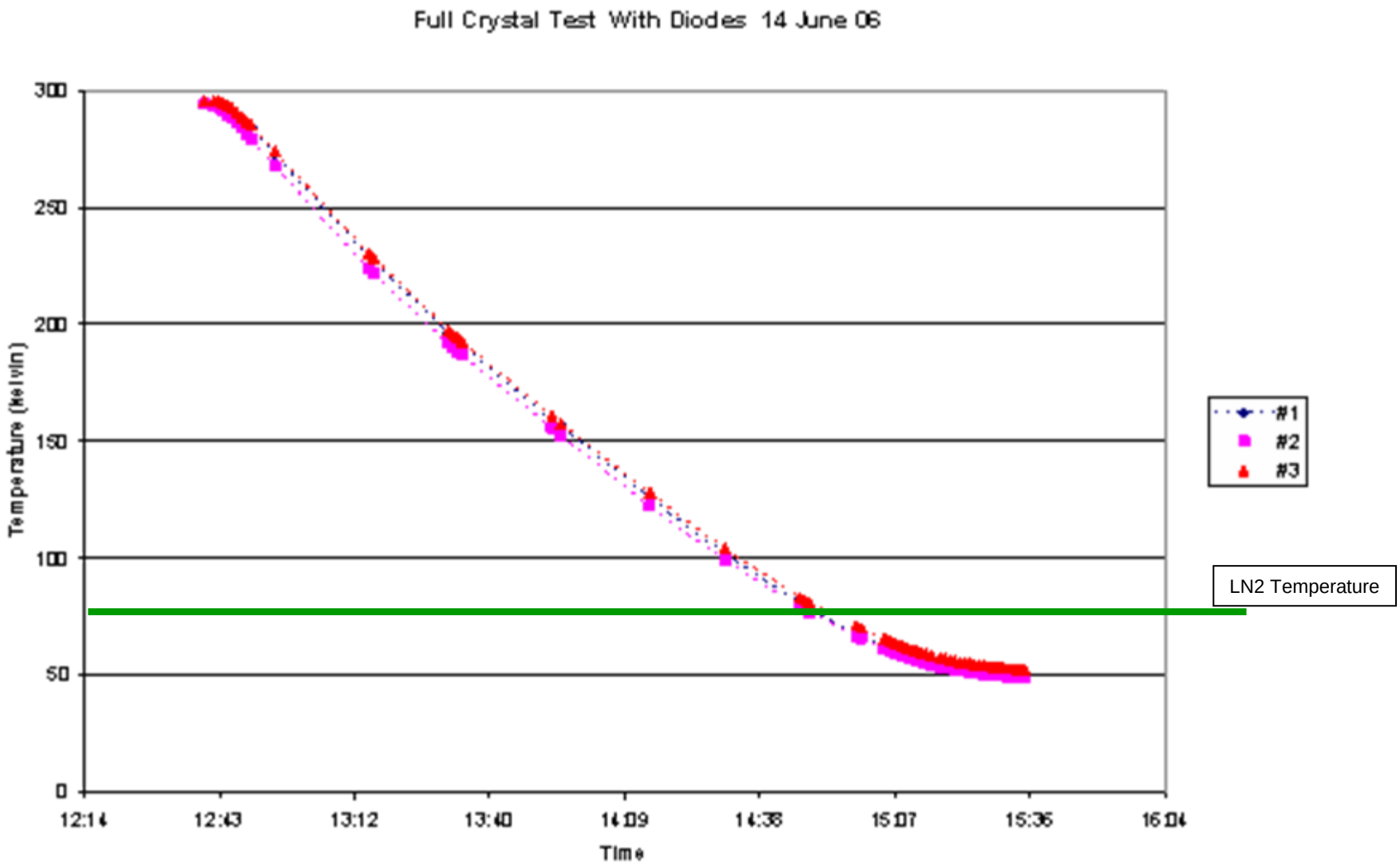








Direct Cooled HTS Bearing Exceeds LN2 Temperature



Summary / Program Status

- **Stability magnet sub-assembly issues were resolved**
- **Direct Cooling approach worked well and exceeded goal of LN2 temperatures**
- **Funding interrupt has slid schedule**
- **Detailed design is ready to move forward**
- **Current plans include fabrication of motor / generator and lift magnet system moving towards full system integration**

Acknowledgements

- **I would like to acknowledge the help, timely advice, and program guidance of:**
  - **Dr. Imre Gyuk of the U.S. Department of Energy through the Energy Storage Program**
  - **Nancy Clark and John Boyes of Sandia National Laboratories**